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LEAD (Pb) ACCUMULATION STUDY IN PLANTS AND VEGETABLES CULTIVATES AROUND COAL MINES AND POWER PLANT OF SINGRAULI DISTRICT

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ABSTRACT

The study of undertaken for heavy metal Pb accumulation by fly ash and coal waste in Singrauli industrialised district of India, using atomic absorption spectrometry. Ashes from collected vegetables and plants leaves samples were analysed for the quality and quantity of Cr, Mn, Pb, Zn, Cu, As, Ni and Co and detectable levels of all were found. Pb distrusted the metabolic processes of living organisms due to variable accumulation in plants and vegetable which affected the human populations through food chain. Presence of Pb and other heavy metals in environment has become a major threat to plant and common vegetable due to their bioaccumulation tendency and toxicity. In present investigation 6 plants leaves *Syzygium Cumini, Dalbergia Sissoo, Dandrocalamus Strictus, Magnifera Indica, Tectona Grandis and Azadiracta Indica* and 6 common leafy vegetables *Spinacia Olaracia, Solanum Tuberosam, Raphanus Sativus, Brasica Comprestis, Trogonella Fonium* and *Momordica charantia* were studies for monitoring or observation of current status of Pb in these plant and common vegetable species growing around the industries of Singrauli district. The Soil profiling were also performed for presence of heavy metals with specificity of quality, resulted indication was observed an alarming situation in Singrauli district of India.

INTRODUCTION: Fly ash is produced as a result of coal combustion, thermal power station and discharged in ash ponds. Now-a-days fly ash disposal in environment is one of the major threats throughout the world. Production of ash depends on quality of coal, which contains a relatively high proportion of ash that leads to 10-30% ash formation [1].

Discharged fly ash used in construction of roads, building and cement industries. The alkaline nature of ash has resulted in attempts at using it as fertilizer or amendment to enhance the fertility of soil.

It contains several heavy metals along with low range of nitrogen and phosphorus and pH ranged from 4.5 to 12 depending on parental coal [2, 3]. Ash is disposed by dry and wet method. Directly or indirectly both ultimately leads to dumping the fly ash on open land. Particles size of ash are very small to escape emission control devices and easily get suspended in air which toxic in nature to causes irritation in eyes, skin, nose, throat and respiratory tract. Therefore, disposal and utilization of ashes needs careful assessment to prevent of arable land into landfills and accumulation of toxic metals in soil [4].

Fly ash has high surface area due to smaller particle size, having water holding capacity is around 50-65% and specific gravity ranged from 2.1 to 2.6gcm^{-1}. Ashes inhibited microbial respiration, number, size, enzyme activity and soil nitrogen cycling processes [5-8].

Mostly vegetables and plants are growing on heavy metal contaminated land which can accumulate high range of trace elements to cause serious health risk in consumers [9]. Based on persistent nature and cumulative behaviour with probability of potential toxic impacts of metals as a result of consumption of leafy vegetables, there is need to analyze these food items to ensure the levels of these trace elements meet the agreed level.

Pb is a very stable metal in soil and is highly toxic to humans and animals. It is non-essential elements, affect plants growth and development. It is recognized as an extremely significant pollutant due to its high toxicity and large solubility in water [10]. An increased concentration of Pb in air, water and soil raises its uptake through live organisms and eatable growing sources [11]. It is taken up by plants and animals through them also by humans. Uptake of Pb by plants and vegetables occurs through roots and leaves from water and soil only in form of Pb ion [12].

The green plants are starting link of the food chain, which is the principal source of Pb to animals and humans. They also accumulate unwanted substances including Pb via pollutant releases by industries, mines and thermal power stations. High range entry of Pb in plants and vegetables is directly concern to cultivation practises around industrialization.

The study area Singrauli is industrialized district, spread over the two States Uttar Pradesh and Madhya Pradesh of India. Populations exit around 185,580 were calculated as per the census 2011 with 85/km^2 (220/sqm) covered density. Various energy generating industries like Singrauli Super Power Plant (SSPP), Vindhyanchal Super Thermal Power Plant (VSTPP), Northen Coal Limited (NCL), Kanoria Chemicals are regularly increases the quantity and types of pollutions via disposing of organic, inorganic, degradative and non-degradative waste materials in local environment which directly and indirectly affect the human health.

Modern civilization and prolonged discharge of industrial effluents and solid waste dump cause the air and ground water pollution to created health troubles [13]. Part of heavy metals gets solubilized in water and become available for plants and vegetables to created health risk or toxicity (Neurotoxicity, hepatotoxicity, nephrotototoxicity) produced via absorption and accumulation of toxicants [14]. They all have in common is that only their absence can eliminate the respective health risk. Therefore it is very essential to recognize the trouble and take appropriate early measures.

Dietary sources account for most of human exposure to Pb except for areas in the vicinity of Pb emitting industries. Pb is taken up by roots of plants and vegetables passes to edible leaves, fruits and seeds. It will also accumulate in animal milk and fatty tissues. Rapid, unorganized industrialization and urbanization have contributed to elevated levels of Pb in urban environment of developing city such as India [15-17]. Plants take up heavy metals by absorbing them from deposits on parts of the plants exposed to the air from polluted environment as well as from contaminated soils [18-19].

In present study, we investigated the concentration of Pb in plants and vegetables cultivated around industries of Singrauli district.

MATERIAL AND METHOD:

Study area: The study area Singrauli district is developed industrialized region, covered coal mine, electricity generation power plants, Energy generating industries like Singrauli Super Power Plant (SSPP), Vindhyanchal Super Thermal Power Plant (VSTPP), Northen Coal Limited (NCL), Kanoria Chemicals and dense forests.

Collection of samples and Soil pH determination: The study were conducted on the leaves of 6 basic arboreous plant species (*Syzygium cumini, Dalbergia sissoo, Dandrocalamus strictus, Magnifera indica, Tectona grandis, Azadiracta indica*) and 6 common vegetable species *(Spinacia olaracia, Solanum tuberosam, Raphanus sativus, Brasica comprestis, Trogonella fonium and momordica Charantia).* These plants and vegetables are frequently and widely cultivated in numerous open lands and farms around established different industries of Singrauli district. Random sampling was done from 200 points all over the region. The leaves samples were carefully collected, labelled and stored accordingly. The pH of the bulked soil near the collected plant and vegetables sampling areas was determined using the electronic method. The health of plants and vegetables with other essential history were recorded.

Washing and Grinding of samples: After collection, the samples were brought to the laboratory and processed for further analysis. Samples leaves of plants and vegetable were properly separated and washed with doubled distilled to remove the dust particles. Sampled leaves were then equally chopped into small pieces using a sterilized knife. The vegetables and plant leaves were air-dried and then dried in an oven at 35 °C. Dried samples were grinded into a fine powder (80 mesh) using a mechanical electrical blender and stored in sterilized poly bags, until used for acid digestion with labelling. The washed water was also examined for the presence of heavy metals.

Acid digestion and analysis of Pb: Heavy metals in arborous species of plants and vegetable samples were extracted following acid digestion procedure in which 1g of the dry weight of each sample were taken in acid digestion test tube and 10ml of 98% nitric acid was added. Further it was placed in water bath and allowed to boil for about 72 hours. Digestion was completed, with pale yellow colour.

A solution was makeup to 25ml with de-ionized water and stored in cool place. The prepared samples solution were analyzed for Cadmium using atomic absorption spectrophotometer (AAS, Perkin Elmer model 1100 B). A certified standard reference material was used to ensure accuracy and the analytical values were within the range of certified value. Blank and standards were run after five determinations to calibrate the instrument.

Preparation of stock standard: In order to prepare the stock standard solution, 1.299 g of $PbNO_3$ (Merck, Germany) was dissolved by using 5% HNO_3 (Merck,Germany) after that, it was decanted into a 1000 ml volumetric flask with 5% HNO_3 and volume was made to mark by 5% HNO_3 solution.

Serial dilution of Stock Standard and Generation of Calibration Curve: The stock standard solution was serially diluted to concentrations of 10, 1.0 and 0.5 ppm. These different standard solutions were used to generate a suitable curve, which was used to calibrate the instrument. After the serial dilution of the stock standard, the different calibrants were fed into the AAS as standard samples. These were used by the AAS to generate a suitable calibration curve. The samples were then run in triplicates and mean values were calculated.

RESULTS AND DISCUSSION: Lead (Pb) is a serious cumulative body poison which enters into the body system via transmission of air, water, food and cannot be removed by washing fruits and vegetables [20]. The leaves samples of different plant and vegetable species have been investigated for the atomic absorption study. The soils were also collected from all the sampling locations as samples and examined for heavy metals profiling purpose. Mostly concentration of Fe, Cr, Cd, Pb, Zn and Mn were recorded. The Fe levels in soils from vegetable and plants farms ranged between 13601.8 and 16260.6 $mgkg^{-1}$. Iron (Fe) ranges were found above the accepted limits of 425.00 $mgkg^{-1}$ for agriculture exploitations as described or recommended by Food and Agriculture Organization-World Health Organization [Codex Alimentarius Commission (FAO/WHO), 2001].

Heavy metals concentrations varied Cd (9.40-32.32), Cr (1115.41-1970.12) and Pb (36.7-58.14) $mgkg^{-1}$ which was above the maximum permitted levels of 0.1, 100 and 0.3 $mgkg^{-1}$, respectively [21]. Similarly the range of Mn, Cu and Zn were accounted in soil between 106.14-153.64, 92.32-113.1 and 54.4-72.6 $mgkg^{-1}$ (**Table 1**). Results of soil profiling indicated about the elevated stages of soil metals contamination, could be attributed to effluents from situated major industries such as thermal power station, Kanoria chemicals, coal mines within the vicinity of district. Other sources of these kinds of contamination could also be due to large volumes of industrial waste fly ash and water that was discharged from industries or mines into the streams. The soil profiling with reference to presence ranges of heavy metals were significantly evaluated, finding suggested that all sampled soils were fully loaded with variable ranges of heavy metals.

The waidhen city was found less contaminated as compared to other three Kanoria chemicals, SSTP and VSTPP sampling sites (Table 1).

TABLE 1: SOIL PROFILING OF DIFFERENT SAMPLING STATIONS SOILS

Heavy metals concentration of plants and vegetables growing soil (Mean±SE)							
Sampling station	**Cd**	**Cr**	**Fe**	**Pb**	**Zn**	**Cu**	**Mn**
Kanoria Chemicals	28.40 ± 3.2	1604.22 ± 1.7	13601.8 ±1.2	58.14 ± 1.6	62.22 ± 1.1	113.1 ± 6 1.6	126.42 ± 2.9
SSTP	22.46 ± 2.1	1812.16 ± 2.6	15426.3 ± 4.6	54.12 ± 2.4	68.14 ± 3.1	106.2 ± 42.5	153.64 ± 3.4
VSTPP	32.32 ± 1.2	1970.12 ± 1.5	16260.6 ± 3.1	43.16 ± 1.6	72.6 ± 0.8	109.6± 1 2.4	139.21 ± 3.8
Waidhan city	9.40 ± 2.6	1115.41 ± 2.2	14134.4 ±2.5	36.7 ± 2.1	54.4 ± 1.7	92.32 ± 3.4	106.14 ± 2.1

The variation of Pb levels depends on the different variety of soil and concern fertility management practices. The applicability of chemical pesticides/ herbicides which was used in the farms around the industrialization also altered the productivity along with metal contaminations. Heavy metal contaminated soils leads to decline the leaf production rate, affected the ovar all plant mass along with poor development of flowers etc [21]. Variable concentration of heavy metals in soils via industrial effluents, sewage influx and ground waters can induce serious problems to soil, cropping, vegetation and in turn living health [22-24]. Heavy metal accumulation by plant tissues, its presence in the soil persistently or its presence in ground waters is not a healthy sign in favour of the environment [24].

a. **Lead in arboreous plants:** Leaves samples of six different plant species of four different sampling stations of singrauli district shows the variable range of Pb concentration. The maximum 2.59µg/gm Pb content was found in *Syzygium Cumine* plant near Kanoria chemical sampling station while minimum range 0.004 µg/gm recorded in *Magnifera Indica* plant grown around Waidhen city samples.

   Similarly 1.52 µg/gm and 1.90 µg/gm concentration were observed in *Syzygium Cumine* around VSTPP and SSTPP sampling stations. Pb stress and its impacts on photo system II of plants affect the photosynthesis process because Pb was not easily chemically degraded or destroyed it's affected the expansion and quality of plant or plant products.

Screened plant *Dalbergia sissoo* is widely distributed in forest, open lands and farms in this district. Pb with excessive range were recorded 2.21µg/gm near Kanoria chemicals area's while lowest 0.02µg/gm concentration were recorded near Waidhan city sampling station. Results suggested that plantation of bamboo was not affected by Pb pollution in that area.

Pb is a trace element with unknown essential functions for plants including bamboo. Short leaves of these plants is not able to observed the dust or ash particle due to less surface area but ionic Pb with other associated heavy metals were recorded on both surface of bamboo leaves under accumulated and disperse condition except waiden city station. The minimized surface area alters in adsorption and adhesion phenomena in case of fruits as comparison to plant leaves.

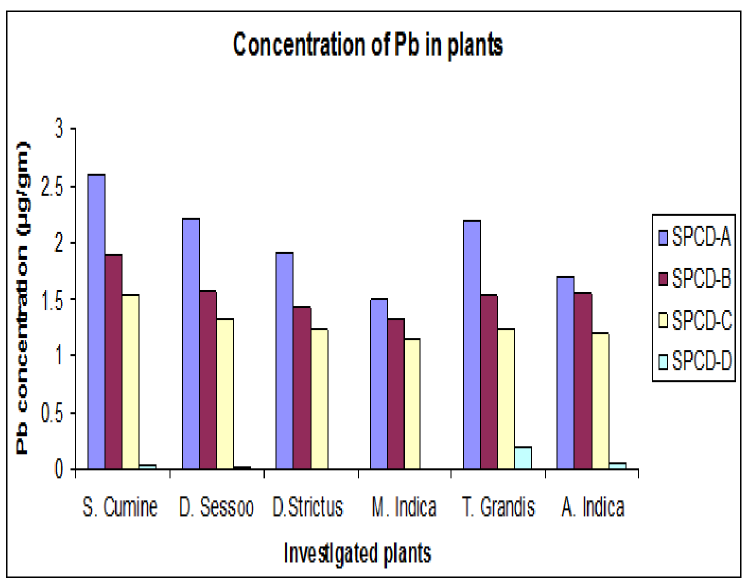

FIGURE 1: LEAD CONCENTRATION IN PLANTS.

Variable range of Pb in investigated plants may probably be attributed to pollutants in farm soil, irrigated water or due to discharged industrial ashes [25-27]. In *Dandrocalamus Strictus*, 1.92µg/gm Pb was detected in polluted region whereas in Waidhen city it was free from Pb accumulation. All the screens out 10 samples of waiden city sampling station were free from Pb concentration mostly. Similarly 1.42µg/gm and 1.23µg/gm range were found for SSTP and VSTPP.

TABLE 2: CONCENTRATION OF LEAD (Pb) IN DIFFERENT PLANT SPECIES

		Pb conc. Mean in plants species					
Sampling station	**Station code**	***S. Cumini***	***D. Sissoo***	***D. Strictus***	***M. Indica***	***T. grandis***	***A. indica***
Kanoria Chemicals	SPCD-A	2.59	2.21	1.92	1.56	2.20	1.70
SSTP	SPCD-B	1.90	1.56	1.42	1.32	1.52	1.54
VSTPP	SPCD-C	1.52	1.32	1.23	1.14	1.23	1.19
Waidhan city	SPCD-D	0.04	0.02	ND	0.004	0.19	0.06

Direct relations have been exit between the presence of Pb in root and whole plants which directly absorption by plants [28-30]. Finding suggested that Ionic Pb was readily absorbed by roots and trans located to above-ground parts to plants create several changes in oxidative and other associated metabolism [31, 32]. Leaves of *Tectona grandis* were broad and susceptible for air pollution and mostly species are found abundantly in this area. Highest Pb concentration on leaves of plants was noticed near Kanoria chemicals about 2.20 µg/gm, while minimum Pb concentration 0.19 µg/gm was recorded waidhan city restricted area of singrauli district.

Ranges of Pb (dry weight-based) are typically highly encountered in plant having wide and rough leaves such as mango. Mostly Pb in form of ions worked as mediator which directly link with free radical and reactive oxygen species [33]. *Magnifera Indica* (Mango) is abundantly present tree in Singrauli district. Pb in field grown crops and plants are usually negatively related to soil pH but the effects are often small or even insignificant [34]. The studies revealed that Pb is a highly mobile metal, easily absorbed by the plants via root and moves to wood tissue and transfers to upper parts of plants [35].

Leaves of mango tree get contaminated by Pb in range between 1.56-0.004 µg/gm as per analysed data. The range of Pb contents was less accounted on leaves curing flowering season of the plants. Negative effects can be expressed as symptoms in the form of chlorotic spots, necrotic lesions in leaf surface, senescence of the leaf and stunted growth

A highly potential medicinal plant, *Azadiricta Indica* is very common in this region. Its stem leaves and fruits documented for medicinal values. Out of 40 samples Pb concentration ranges in between 1.70-0.06 µg/gm. results shows that uptake of Pb is not equivalent to other plants. Regular enrolment of Pb with other metals with plants created genetic variations due to genotoxic and ecotoxic nature of Pb in animals also [36-38]. It can alter the uptake of other essential minerals by plants through its effects on availability of minerals from soil, or through a reduction in population of soil microbes [39], our finding indicated the range of Pb inhibit the uptake of minerals from soil due to binding ability of Pb with other potential minerals which was directly concern with root xylum along with floeum of plants.

Chlorosis, leaf rolls and stunting are the main and easily visible symptoms of Pb toxicity in plants. Pb is known to negatively affect some of the most classical endpoints of plant toxicity like seed germination rate, seedling growth, dry mass of roots and shoots, photosynthesis, plant water status, mineral nutrition, and enzymatic activities [40].

In general, effects are more pronounced at higher ranges and continuance. In some cases, lower concentration can stimulate metabolic processes and the enzymes involved in those processes [41]. Development and growth of root and shoot in seedling stage are also affected being roots more sensitive. Similar finding were observed and documented, potential stunting observed in leaves stem areas in plants.

b. **Lead in Vegetables:** In Singrauli district there has been a rich practice for growing vegetables. Due to industrialization many of vegetable gardens and farms have been converted into industrial area, even then the vegetables are growing in urban and rural areas, which is in vicinity of ash ponds, power plants, coal mines and industries. Several reports have documented that common vegetables are capable of accumulating high levels of metals from soils[42,43]. Studies conducted with edible vegetables species revealed the correlations between the Pb content in soils along with environment and its effects in vegetables.

Present study was conducted in six common used leafy vegetables cultivated frequently. Vegetables constitute an important part of the human diet since they contain carbohydrates, proteins, as well as vitamins, minerals and trace element[44]. Sampling sites were selected for vegetables lead analysis around the industrial area the results are being tabulated in **table 3** as follows:

TABLE 3: CONCENTRATION OF LEAD IN COMMON VEGETABLES.

		Pb conc. Mean in vegetable species					
Sampling station	**Station code**	***S. Olaracia***	***S. Tuberosam***	***R. Sativus***	***B. comprestis***	***T. Fonium***	***M. charatia***
Kanoria Chemicals	SVCD-A	0.09	0.09	0.09	0.09	0.05	0.06
SSTPP	SVCD-B	0.06	0.05	0.07	0.07	0.03	0.08
VSTPP	SVCD-C	0.08	0.02	0.06	0.05	0.04	0.05
Waidhan city	SVCD-D	1.03	0.70	1.01	0.92	0.72	0.86

Observation resulted the Pb comes through environmental air pollution which directly accumulated, observed and dispersed in aerial part of growing vegetable plant. Pb contents in each sample were analysed in triplicates, the number of samples collected in between 10-50 for each. In case of spinach, out of four sampling stations the Pb contents were in range of 0.06-1.03µg/gm. Pb (0.08µg/gm) content was recorded in VSTPP sampling station whereas 0.06µg/gm minimum value was accounted in SSTPP sampling station (Table 3).

Elevated levels of Pb in vegetables observed in this study may be due to physical and chemical nature of soils in the farms, absorption capacities of Pb by vegetables and atmospheric deposition of Pb. The high levels may also be influenced by environmental factors such as temperature, moisture, wind velocity and the nature of Plants [44]. Study varied in the concentrations of Pb which could be as a result of anthropogenic activities such as addition of phosphate fertilizers or use of metal-based pesticides in farms and urban industrial activities.

Mostly An important possibility was also concern with pesticides treatment which may also be the causes of Pb toxicity. Pb was higher accounted in aerial parts as compared to below the ground. Pb content alters the mechanism of photosynthesis which directly and indirectly affected the chlorophyll production in Spinach. High accumulation of lead, chromium and cadmium in leafy vegetables due to atmospheric deposition [45, 46]. The potato leaves are being affected by Pb concentration in range of 0.02-0.70µg/gm. Pb concentration was recorded 0.02 >0.05 >0.09 and 0.70, in which minimum value was obtain in Kanoria chemicals samples whereas near SSTPP samples was shown maximum value. Soil salinity increases the Pb uptake in field grown vegetables [46, 47]. Pb is considered to have low solubility and availability for plant uptake because it precipitates as phosphates and sulfates in the rhizosphere of plants to inhibits seed germination, plant growth and chlorophyll synthesis, among other effects [48-50].

Pb in radish has also been detected in range of 0.06-1.01µg/gm. Pb is highly mobile in nature, easily absorbed through soft root of the radish and moves to tissues and continuously transfers to topwords [48, 51, 52]. Pb in mustard has been found to be in the range of 0.15-0.92 µg/gm.

It is possible that mustard catch Pb easily hence the uptake and transport is more as compared to other vegetables. Pb negatively influences growth by reducing the uptake and transport of nutrients in plants, such as Ca, Fe, Mg, Mn, P and Zn and by blocking the entry or binding of the ions to ion-carriers making them unavailable for uptake and transport from roots to leaves [35].

Moreover, the roots of vegetables also contained a range of heavy metals; the same trend in shoot was also notified. Some plant species there was higher ranges in shoot than the roots. In case of fonium vegetable the range of Pb 0.03-0.72 µg/gm and in *M. charantia* 0.05-0.86 µg/gm was recorded (Table 3). The higher ranges of Pb with *M. charantia* may moreover for the reason of much susceptibility of Pb for *M. charantia*. Finding suggested that several plants could accumulate Pb in their tissues to more than 50 mg/g dry weight of plant. Pb concentration is found to be more near ash areas, reason being that Pb in ash of the areas takes a path through aquatic system which moves in soil, where Pb gets transported in plants through roots of vegetable [55].

The main cause concern in terms of contamination of vegetables in Singrauli region by heavy metals relates to Pb. Although a maximum Pb limit for human health has been established for edible parts of crops is 0.2 mg kgG1 [56] but this limit by WHO standards is 0.3 mg kgG1 [56]. Data showed that in all vegetables, Pb concentration is under permitted level, so they are suitable for consumption. Plants usually show ability to accumulate large amounts of Pb without visible changes in their appearance or yield.

In many plants, Pb accumulation can exceed several hundred times the threshold of maximum level permissible for human [57]. Introduction of Pb into the food chain may affect human health and thus, studies concerning Pb accumulation in vegetables have increasing importance[57]. On the whole, all vegetables that were studied in this study were contaminated by lead and they were toxic to consumer.

CONCLUSION: After investigations the above mentioned studies it may be concluded that monitoring and assessment of heavy metal (Pb) concentrations negatively affected the growth and productivity of both plants and vegetables species. Findings of our investigation substantiate the conclusions. Pb from thermal power effluents absorbed by surface of plants and vegetables leaves which create toxicities with alteration on plants structures, photosynthesis, pigment, enzymes, hormones production etc. Leafy vegetables have been shown to accumulate relatively high range of Pb in compare to fruit vegetables.

Less accumulation of Pb recorded in leafy vegetables leaves as compared to plant leaves. Several environmental problems such as land degradation, ground and surface water contamination were also associated as results of pb toxicity. Thus, regular monitoring of these toxic heavy metals from effluents and sewage, in vegetables and in other food materials is essential, to prevent their excessive build-up in the food chain. Cheaper and effective technologies are needed to protect the precious natural resources and biological lives.

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